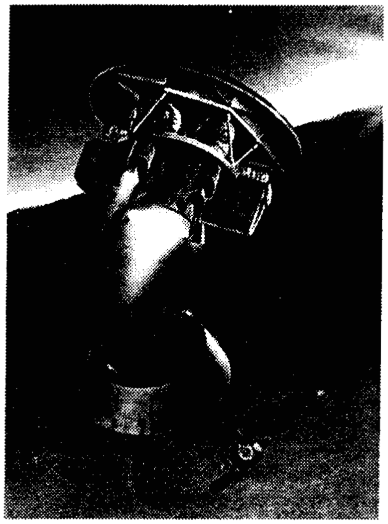

A Few Good Rocks:
The Mars Sample Return Mission Architecture

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A Mars sample return is the culmination of many years of exciting missions of the Mars Surveyor Program. Analyzing samples of Martian dust and rocks in laboratories on Earth is a goal of scientists and engineers since the Viking missions in the mid-1970's. Launching in November, 2004, the Mars Sample Return (MSR) mission will bring back about 1 kg of Martian rocks and soil in April, 2008. Like all missions of the Mars Surveyor Program, MSR builds upon previous Mars missions to enable an exciting mission at a fraction of the cost and risk of a stand-alone mission. We describe the MSR science rationale, mission architecture, trajectories, flight systems, and challenges.

Rationale for sample return

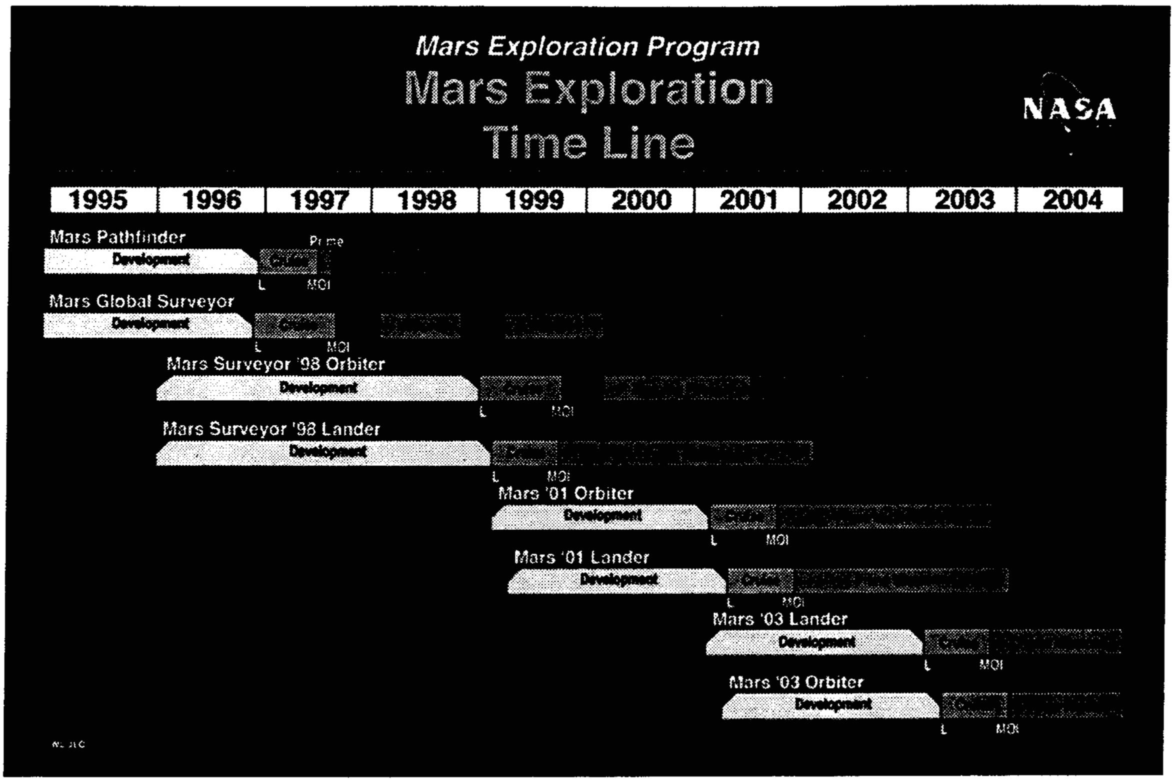
*** insert graphic of Mars Program rationale here***

Mars is a vast planet. In fact, the surface area is roughly equivalent to Earth's continental land surface areas combined. Exploring and understanding the Red Planet requires observations on a global basis with orbiters. And, in-situ measurements on the surface are required for ground truth, just as in Earth investigations.

Despite the past, present, and future successes of Viking, Mars Pathfinder, Mars Global Surveyor, Mars 98 Orbiter and Lander, Mars 2001 Orbiter and Lander/Rover, and Mars 2003 Orbiter and Lander/Rover, there is a limit to what robotic exploration can observe. Many tests for past or present life require that a sample be brought to Earth laboratories for years of intense study.

Obtaining a good set of samples for return requires that we study Mars with the previously mentioned orbiters, landers, and rovers. These missions allow us to find the most intriguing sites within engineering and budget constraints. This "pathfinding" will allow MSR to return a scientifically exciting set of samples for study.

Mars Surveyor Program background



The Mars Surveyor Program has multiple sample returns as a goal. The earliest a sample return is possible given the current state of knowledge of Mars and the available budget is 2005. MSR relies upon the 2001 and 2003 rovers to collect and cache a set of samples for future return to Earth.

MSR then chooses the best site from the 2001 and 2003 caches and returns that sample to Earth. This leaves the remaining cache which can be retrieved in a future Mars opportunity.

Mission Overview

*** insert MSR overview graphic and schedule here***

MSR launches on a medium class launch vehicle (Delta III or Atlas IIAR size) from Kennedy Space Center in November, 2004. The orbiter functions as the cruise stage for the lander with rover. After approximately a 2 year cruise to Mars, the orbiter detaches from the lander and does a deflection maneuver as close as possible to Mars entry. The orbiter then proceeds to a Mars Orbit Insertion (MOI) into an elliptic orbit with a period of around 12 hours. This orbit is gradually reduced to circular by aerobraking in the Martian atmosphere. Aerobraking takes about 6 weeks.

After separation from the orbiter, the lander proceeds to enter the Martian atmosphere. After sufficient reduction in velocity, the aeroshell and heat shield are jettisoned and a parachute is deployed. At an altitude of a few kilometers above the local surface, the parachute is cut and the lander's rockets begin to fire. Terrain recognition and beacon finding allow the lander to maneuver to a touchdown within about 100 meters of the 2001 or 2003 sample cache.

Then, a fetch rover is deployed that will go out and retrieve the sample cache and bring it back to the lander. The cache is placed on the lander. An arm on the lander acts as a backup in case the cache is not recovered. The arm can grab sufficient sample to fill up the lander with soil from the immediate area of the lander. Then, as soon a possible, the Mars Ascent Vehicle (MAV) will launch from the lander into an approximately 240 km circular orbit.

Meanwhile, if the orbiter is now in a circular orbit, the orbiter will rendezvous with the MAV after a series of maneuvers taking up to a week. If the orbiter is still aerobraking, the MAV will wait in its orbit until the orbiter finishes aerobraking. Then, rendezvous with the MAV by the orbiter will begin.

After rendezvous with the MAV, the orbiter transfers the sample to the Earth Return Capsule (ERC) inside the Earth Return Vehicle (ERV). When the geometry is correct for injection to Earth, the ERV burns once to inject into an elliptical orbit about Mars. Then at apoapsis, any necessary plane change is accomplished, followed by the trans-Mars injection at periapsis.

Close to Earth, the ERV will do its final targeting maneuvers. After this, the ERV will detach from the ERC, leaving only the ERC to enter the atmosphere ballistically. The ERC is targeted from a touchdown at the Utah Test and Training Range (UTTR) near Dugway, Utah.

The sample is returned around April 1, 2008. After initial checks, the sample is transferred to a sample return examination facility. Then, the long process of examining the Mars samples can begin.

Launch, Trajectory, and Navigation

insert launch geometry, Earth - Mars trajectory, Mars targeting b-plane, Mars orbit, trans-Mars injection, Mars-Earth traj, and Earth targeting b-plane plots here

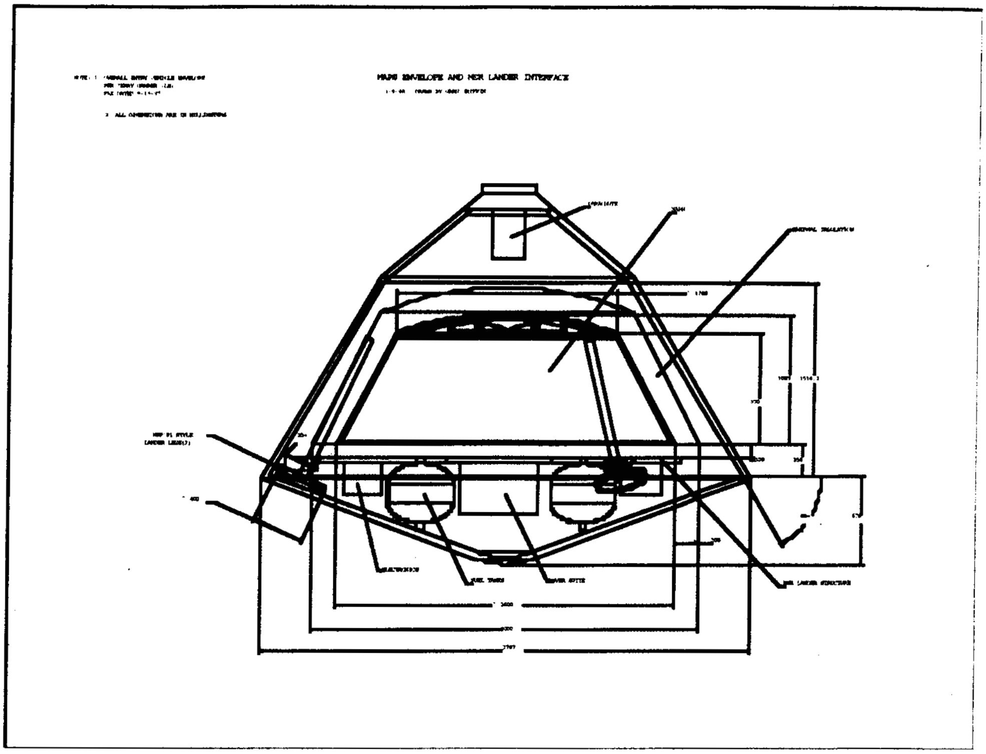
Mars Sample Return launches on a medium class launch vehicle such as the Delta III or Atlas IIAR. A November, 2004 launch with a 20 day launch period yields a maximum required C3 of about 9.6 km2/s2. The declination of the launch asymptote (DLA) exceeds the latitude of the launch site during the middle part of the 20 day launch period. This means the launch vehicle will need to yaw steer during the ascent for those days where the DLA exceeds 28.5º.

The Earth-Mars trajectory is a type 4. This trajectory is chosen because of the lower C3 requirements and Mars approach velocity. Another trajectory option is the 2005 type 2 launching in September, 2005. However, this trajectory requires about a C3 of 17 km2/s2 which is probably out of the capabilities of the medium lift launch vehicle slated for MSR use. A larger launch vehicle could enable this trajectory, but that currently is not anticipated by the Mars Surveyor Program.

*** insert ΔV and nav error tables here***

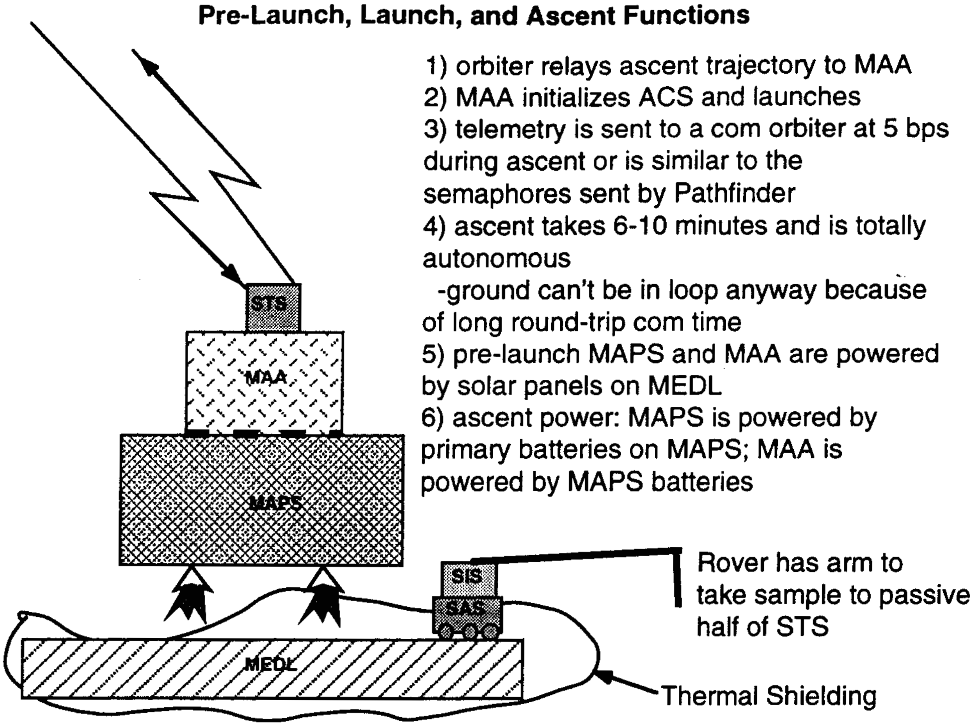
Flight systems

insert graphics of the orbiter, lander, MAV, ERV, sample return capsule



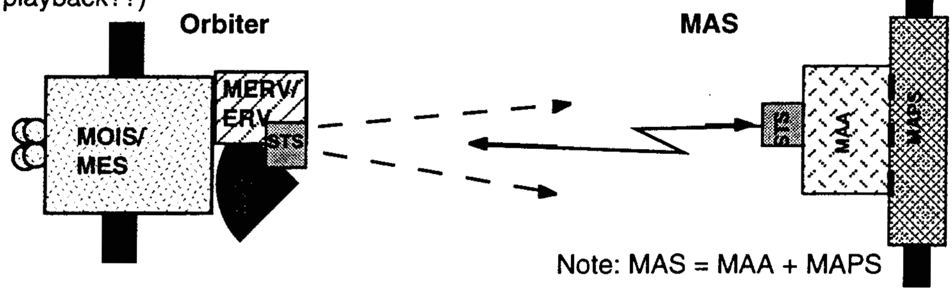
Pre-Launch, Launch, and Ascent Functions

1) orbiter relays ascent trajectory to MAA
2) MAA initializes ACS and launches
3) telemetry is sent to a com orbiter at 5 bps during ascent or is similar to the semaphores sent by Pathfinder
4) ascent takes 6-10 minutes and is totally autonomous
  -ground can't be in loop anyway because of long round-trip com time
5) pre-launch MAPS and MAA are powered by solar panels on MEDL
6) ascent power: MAPS is powered by primary batteries on MAPS; MAA is powered by MAPS batteries



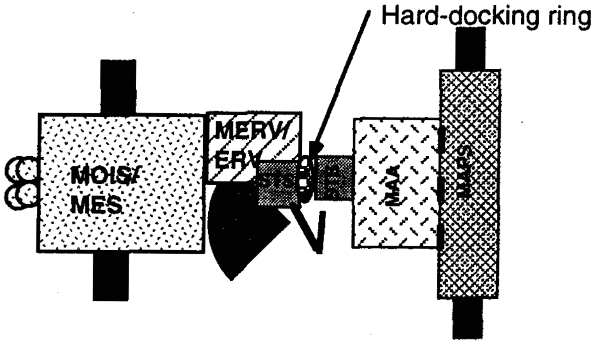
Orbit, Rendezvous, and Docking

1) orbiter locates MAS by means of beacon (days or weeks to rendezvous)
2) MAA maintains attitude/ altitude; is powered by solar panels and secondary battery
3) orbiter performs autonomous docking maneuvers
  -ground can get in the loop and try again (MAA has receiver)
  -ACS needs to be on (or have fast init mode) in case ground wants to un-dock and try again
4) both MAS and orbiter must be oriented to get Sun to solar panels over maximum time during rendezvous and docking (rendezvous should be in Sun)
5) MAA provides thermal control for itself (not MAPS)
6) MAA sends telemetry to orbiter to ascertain health - it's operating and maintaining attitude and altitude - 5 minutes twice a day at 5 bps (ascent data playback??)



Sample Transfer

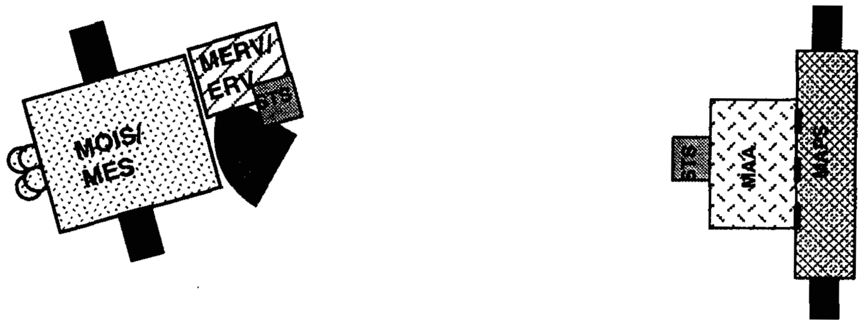
1) once docked, autonomous sample transfer occurs in less than 1 hour
2) MAA thrusters disabled (so both ACS systems aren't fighting each other)
3) sample transfer mechanism is on orbiter and is To Be Defined
 -assume hard-docking



Note: EEDL should really be on centerline

Separation

1) thrusters on MAS and orbiter disabled at separation
2) orbiter autonomously separates from MAS, re-orients for Mars escape
3) MAS job is finished.



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Descriptions of all major MSR systems.

<u>Challenges and Conclusions</u>

Mars Sample Return will be an exciting and rewarding mission. Using the caches left by the 2001 and 2003 Mars Surveyor rovers enables this mission to fit within the cost and schedule limitations of the Mars Surveyor Program. Continuing challenges include fitting the flight systems inside the medium class launch vehicle performance envelope and shroud size.

Autonomous orbit rendezvous to transfer the sample from the MAV to the ERV is currently under study. This new technology at another planet must work for sample return to be successful. Precision landing to within 100 meters of the sample cache requires new technology in terminal descent and beacon signal acquisition.

In a little over 10 years from now, Mars soil and rock samples will be returned to Earth. The study of these samples in the world's laboratories will shed new light on the Martian environment and the possibilities for previous or current life.